University of Adelaide

COMMEMORATION ADDRESS
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ENGINEERING AND THE UNIVERSITY

Engineering is the Cinderella among the professions. You will remember that Cinderella was not only the youngest among the sisters, but she it was who was the maid-of-all-work while they got all the education and all the fine clothes and went out to balls and parties, until that happy time arrived when she married the Prince. And so from the very beginnings of Universities it was thought right and proper that they should undertake the training of lawyers, physicians and surgeons, clergymen, teachers and philosophers. All of these belonged to professions which were recognized as deserving of that training in knowledge and culture that only the Universities could give, but for the men who were to be engaged in the practical work of building roads and bridges, reservoirs and canals, and otherwise administering to the physical wants of the people, the Universities for a long while had no place.

It seems rather strange that this should have been so, because if we go back far enough we find that the smiths, the workers in iron, who were the forerunners of the modern engineers, occupied a place of great importance in all primitive communities. They supplied tools for the carpenter, spades and hoes for the farmer, and the keys, bolts and ironwork for the castle. The community depended upon them for the weapons of the chase and for the weapons of war. They made the bills and battle-axes, the tips for the bowmen's arrows, and the swords and

spear-heads for the men-at-arms. "More important than all, they forged the mail-coats and cuirasses of the chiefs, and welded their swords, on the temper and quality of which life, honour, and victory in battle depended." There is small wonder then that in Anglo-Saxon times the person of the smith was protected by a double penalty. He was treated as an officer of the highest rank, and awarded the first place in precedency. After him ranked the maker of mead, and then came the physician. In the royal court of Wales he sat in the great hall with the King and Queen, next to the domestic chaplain.

A story is told of a Highland clan whose smith committed some act of robbery on a neighbouring clan, for which his execution was demanded. The chief, however, explained that he could not afford to dispense with the smith, but he generously offered to hang two weavers in his stead.

But the art of the smith, in those days and for long afterwards, was purely empirical. It could be successfully learned and practised by men who could neither read nor write. It had no basis of scientific knowledge. With the growth of requirements due to the development of large towns, some members of the great Smith family became manufacturers, as at Sheffield and Birmingham; others enlarged the scope of their activities to include more of what we now understand by engineering work. Masons became bridge builders. But the fountains of science, from which the young engineering giant was to be nourished, were as yet unknown at the time when the first Universities were established. At the University of Paris the four faculties were Theology, Law, Medicine, and Philosophy, which were represented as the four streams of learning that were like unto the rivers of Paradise. But in this Paradise science had no part, and of practical applications of science there could be none. A well-known

definition of civil engineering states that it is "the art of directing the great sources of power in nature for the use and convenience of man." As a broad definition this would be difficult to improve upon, and it is obvious that until science had developed far enough to be able to enunciate the laws governing the forces of nature it was impossible to have anything but empirical rules to govern engineering design and construction.

And so Engineering remained a trade, while Medicine and Law advanced in dignity and status. It became a tradition in Engineering that the only school worth anything was the school of practical experience. Even long after the sciences of Mechanics and Hydraulics had become well established courses at Universities, such studies were neglected by engineers whose hard practical training tended to give them little sympathy with the abstruse and often impractical and unreal problems commonly discussed by the mathematicians. From this position, at the end of the 18th and beginning of the 19th centuries, Engineering was rescued by a series of eminent men who, while they were all trained in the first instance as tradesmen, distinguished themselves by the zeal with which they assimilated scientific knowledge from any source available to them.

Thus Telford, nicknamed by his friend Southey "Pontifex Marimus" and the "Colossus of Roads," one of the first of the iron bridge-builders, started life as a working mason. When still on the first rungs of the ladder he so successfully climbed, he wrote in one of his letters: "I am not contented unless I can give a reason for every particular method or practice which is pursued. Hence I am now very deep in Chemistry. The mode of making mortar in the best way led me to inquire into the nature of lime. Having, in pursuit of that inquiry, looked into some books on Chemistry, I perceived the field was

boundless; but that to assign satisfactory reasons for many mechanical processes required a general knowledge of that science. I have therefore borrowed a MS. copy of Dr. Black's Lectures. I have bought his 'Experiments on Magnesia and Quick Lime,' and also Fourcroy's Lectures, translated from the French by one Mr. Elliot, of Edinburgh. And I am determined to study the subject with unwearied attention until I attain some accurate knowledge of chemistry, which is of no less use in the practice of the arts than it is in that of medicine." Such persistence and perseverance could not but attain success, and the result is to be seen to-day in the lasting qualities, that have been the admiration of succeeding engineers, of the lime concretes in the canals and other structures built by Telford. Both Fairbairn and George Stephenson received their first training at a colliery at Newcastle. Later in life, when Fairbairn had become a man of world-wide reputation as an engineer, he was elected President of the Institute of Mechanical Engineers at a meeting held at Newcastle, the scene of his work as a boy, and in the course of his address he said that had it not been for the opportunities for self-education that Newcastle offered, opportunities that we should think very small now, and the use of the library at North Shields, he believed he should not have been there to address them. "Being self-taught, but with some little ambition, and a determination to improve himself, he was now enabled to stand before them with some pretensions to mechanical knowledge, and the persuasion that he had been a useful contributor to practical science and objects connected with mechanical engineering."

But the methods and reasoning by which such men arrived at their practical designs could not be expected to coincide with the methods of the academic exponents of the principles of mechanics, and it is hardly surprising to find Todhunter, in his History of the Theory of Elasticity,

writing with reference to the papers written before the Institution of Civil Engineers in the period 1850-1860:

"The scientist stands aghast at the great mechanical results which have been obtained often by a defective, sometimes by a false theory. Perhaps it is only a consciousness of the large 'factor of safety' used which makes a railway journey endurable for a scientist after a perusal of some of the technical papers published in this decade."

Todhunter was probably seeking in those papers for results that it was not the aim of the writers to produce, and with all his scientific knowledge he would have been quite incapable of doing what these men did. The fact remains that they did build bridges that have carried heavy traffic safely for a century, that they did build railroads and locomotives which served their purpose well, that they did construct effective roads and harbours, and if in many cases the design was neither the best possible nor the most economical, the engineers at least generally erred on the safe side.

But I will not attempt to trace the development through those decades of last century when the question of Theory versus Practice was so vehemently debated. The matter has been settled by the decisive logic of events. The innumerable applications of scientific discovery to practical engineering, and especially the rapid growth of Electrical Engineering, have made it absolutely necessary that a modern engineer worthy of the name should have some knowledge of science. The older method of training for the young engineer was that he should be articled to an engineer in practice, and, apart from the training he received in office and works, he got no scientific training unless he were enthusiastic enough to attend evening classes in some technical institution. This has proved to be entirely insufficient for modern requirements. And so it has come about that although Engineering Schools at

Universities are still for the most part less than fifty years old, they are now associated with almost all Universities. In many the Engineering School is, numerically at any rate, the strongest school of all. The Queensland University began with Schools in Arts, Science, and Engineering, and none in Medicine nor Law. So did the University of Western Australia. Even the Institution of Civil Engineers, a body of practical professional men, for long holding very conservative views with regard to methods of training of Engineers, has for some years recommended a minimum course of three years at the Engineering School of a University, the recommendation being unanimously adopted by the committee appointed to report upon the subject.

The first country to establish schools of advanced teaching in Engineering and Technical Science was France. The military needs of the country, felt in the years preceding the French Revolution, resulted in the establishment by the Government of a number of schools that are still in active work at the present time. The School of Bridges and Roads (Ecole des Ponts et Chaussées) was founded in 1747, the School of Mines (Ecoles des Mines) in 1783. It was not till much later that the first British School of Engineering was established at University College, London, in 1828. Rankine was appointed Professor of Mechanical Science at Glasgow in 1855. Since then Engineering Schools have been established at one University after another, until to-day even Cambridge has its Engineering laboratories and a Mechanical Science Tripos, and Oxford its Department of Engineering Science.

In the address given by the Governor, Sir Drummond Jervois, at the laying of the foundation-stone of the Adelaide University in 1879, he said: "But the engineer, whether he is to be a railway engineer, or mining engineer, or a mechanical engineer, whether he learns classics or not, must, in addition to a knowledge

of mathematics, be instructed in the practical engineering science connected with the branch of the profession which he intends to follow. I may here remark that the present staff of the University does not provide for this kind of instruction, but this deficiency, I trust, will ere long be supplied.'' We were a good many years before we attempted to make good the deficiency referred to by His Excellency, but having now put our hands to the plough I trust that the vigour of our progress will atone for the length of our neglect.

The first object of an Engineering School at a University is to provide that foundation of scientific knowledge which is necessary to the young man entering upon the engineering profession. We may state at the outset that no University or Technical School in the world can furnish the complete training for an engineer. The scientific laboratories of a University cannot possibly give the same kind of experience as that obtained in practical workshops or on the construction of large works. It is not sufficient for a man to know how to test cement and gravel in order that he may determine in what proportions to mix them so as to obtain the densest possible concrete; he must know how to handle his materials, what are the best appliances for the purpose, and how to order his men when he has to make a few hundred cubic yards of it. It is not enough that he should be able to compute the stresses on the various members of a bridge, and even to produce a creditable design; he must know how to erect it without killing his men and without ruining the contractor. If he is a mechanical engineer, he must have that practical knowledge of workshop methods that will enable him to design an engine or machine that will not only work when made, but which can be constructed at a reasonable cost. If he is a civil engineer, he may be required to determine the appliances to be used, and to order the work of large gangs of men in the shifting of

thousands of cubic yards of earth or rock in cutting, dam, or embankment, and it has to be done to leave a margin of profit. If he is a mining engineer, he must determine safe working methods of extracting ore from a mine whose existence depends upon the ore being won at less cost than the value of the contents. In all of these instances the cost of the operation is a first consideration, and it is obvious that it is only by actual experience in the handling of large numbers of men and big quantities of materials that any man can become competent. Clearly this kind of experience is not to be got at a University. University lectures may assist by setting out certain general guiding principles, but proficiency in such work is only to be obtained by actually doing it. If this were all that a University could do it would not be worth while to have an Engineering School at all.

But, on the other hand, there is a kind of knowledge equally essential that the University can give and that cannot so well be gained on practical works. It is the knowledge based upon the experiments and deductions of the great scientific men who have preceded us, and the outlook that is gained by an insight into their methods of inquiry. A man using only the materials gained in his own limited experience, no matter how full it may be, can at the best build but a small and feeble structure. But if he takes the trouble, first of all, before he builds it, to climb to the top of the great hill that has been raised in the course of generations by the great men of the past, the army of scientific workers of all nations, then, building his own edifice on top of that, a man may raise himself to an elevation that shall command the broadest possible outlook. If, however, he build upon the plain below, his view will always be narrow and limited.

Take as an illustration the case of an engineer working with that great building material of recent times, reinforced

concrete. Concrete alone is a material strong to resist compression, but weak in tension. It is a simple idea to reinforce it by embedding steel rods in it so as to compensate for this defect and enable the combined material to resist stresses of both kinds. But to actually carry the idea out it is necessary to know the character of the stresses to which the structure is subjected, so that the steel rods may be placed in such directions, in such places, and in the right quantities as to be able to supply the tensile strength required, and so that steel may not be wasted by being placed where it is not wanted. It is safe to say that no man can do this from his own experience alone. The construction of the graceful arch bridges of reinforced concrete, now so common, and of the large variety of other structures in which the same material is used, has been made possible only by the application to the problem of methods of calculation based upon knowledge of the elasticity of materials that has been slowly gathered through many generations, and the theories developed have been checked at every stage by elaborate tests and experiments, in which engineers have applied the methods of experimental science. The great development in the use of this structural material would have been quite impossible otherwise.

At the discussion before the Institute of Civil Engineers on a paper describing the bridge erected over the Zambesi River, just below the famous Victoria Falls, a story was told of a chief of the Barotse, one of the neighbouring tribes, who came almost daily and sat down and watched the building of the gossamy web of steel that was gradually extended over the gorge, 400 ft. above the water below. He said it was impossible that a small thing like that could carry anything, and that it would be dangerous to walk over it. When it was completed, and he found that a train could go over it, he said it was the finger of God that kept it up. And there is a sense in which the old chief was

right. For the finger of God is surely the compelling power of the laws of Nature, and the erection of such a structure is made possible only by the accurate calculation of the forces acting upon each member of the bridge in accordance with those laws; a computation that no man could make from the knowledge won by his own experience alone.

There are some branches of Engineering, such as Electrical Engineering, that have obviously been almost entirely dependent for their advancement upon scientific investigation, but there are no branches that can progress without it. James Watt, who was trained as a maker of scientific instruments, showed keen appreciation of this fact when he completed his inventions relating to the steam engine by the invention of the indicator. This is the scientific tool that enables the performances of engines to be weighed and measured, and the progress of both steam and gas engine since Watt's time has been largely due to its use. Indeed such progress would have been impossible without it. Yet a recent editorial in "Engineering" lamented the fact that even now some British makers of engines will persist in acting as though the indicator did not exist, with results very harmful to British trade. The relation of the indicator to the steam engine typifies that between scientific method and engineering generally. It is everywhere the active agent that stimulates progress. Even in branches of Engineering commonly regarded as purely practical arts, such as road engineering, experience has shown that the most successful engineers are those who apply to the practical problems minds having knowledge of related sciences and trained in scientific method, and in several American Universities special Degree courses are now given for Road Engineers. Every branch of Engineering has the same story to tell. You all know what a vital force was scientific engineering in the great war. The Germans had the first advantage, largely because for a

generation they had devoted the energies of a large proportion of their scientific men to the devices of military engineering. And we did not beat them until we had proved that we possessed knowledge as profound, and powers to apply it, at least as keen as theirs.

Even more important than any direct knowledge that a young man gets from University studies is the viewpoint that he gains. The outlook of a man with a scientific training is entirely different from that of the man with practical experience as his only guide. He is best equipped to take the broad view and subjugate petty personal feelings in a search for the knowledge necessary to the solution of a practical problem. Some years ago a young graduate of this University obtained a position as surveyor on a large mine. For two or three years his duties took him into every corner of the underground workings, and, although his actual experience of such work was small—nothing at all compared with that of the underground manager, who had been all his life at similar work—he formed the opinion that the methods of working and the whole organization of the mine could be greatly improved. Having carefully thought out his plans, he put his suggestions forward, only to have them laughed at. But he persisted, and as the mining operations were then a source of great worry to the general manager, he was at last listened to, and was given the task of conducting a special enquiry into some of the problems involved. The ultimate result was that the mine entered upon a new life, with permanent improvements economically, and with a definite advance in reduction of risk of operation. He succeeded in making a marked reduction in working costs, he turned a dangerous mine into a safe one, and made a notable advance in methods of mine organization. He did not learn those methods at the University, but I believe that he did get the outlook which enabled him to view the problem in a new light largely as

the result of his University studies. Yet the character of the work would usually be regarded as essentially the province of the purely practical man.

The value of trained engineers to the State was recognized by the late Hon. J. H. Angas, who founded the scholarship that bears his name for the express purpose of enabling young civil engineers to obtain training and experience abroad, in order that they may be better equipped to assist in the development of the State. The scholarship has been awarded biennially since 1888, the successful candidate receiving £200 a year for two years to enable him to benefit by experience in England or America, but unfortunately, of all the past recipients, only three are now in South Australia. It certainly is much to be regretted that we do not induce a greater proportion of the Angas scholars, who represent the pick of our engineering graduates, to come back to South Australia, and so carry out the intentions of the founder of the scholarship. So much of the civil engineering work of the State is under the control of the Government that this can only be secured by their help and co-operation, but surely no better recruits could be got for the service. Last year the total expenditure of the State was £6,450,000, more than one-third of which was spent on railways, harbours, roads, irrigation, and other engineering undertakings. This is a very large sum, and unless we have thoroughly efficient engineering departments hundreds of thousands of pounds may easily be wasted and few know anything of it. The proper way to secure this efficiency is to start with the young men entering the service. Either they must enter properly qualified, or they must become qualified before they can get beyond a certain stage. But it is an anomaly in several of the States that whilst Parliaments have for many years given considerable grants in aid of various forms of technical education, and by speech and deed such training is

recognized by all political parties as of the greatest value to the State, yet little practical encouragement is given, either to the young men already in or to those about to enter Government engineering departments, to make the effort necessary to benefit from the instruction supplied. The new regulations about to be introduced into the South Australian service by the present Government will improve the present conditions in this State considerably, but a still closer co-operation between the University and the Government engineering departments is desirable. Other things being equal, experience in all countries has amply proved that the trained man is bound to make the best engineer in the long run, and there is every reason why the Government service should have recruits of the highest efficiency.

But besides the training of the young engineer in the foundation principles of his profession, there is another object of a University engineering school that is of even equal importance. Indeed, some of our big University brothers have been telling us that unless we keep this object well to the fore we cannot be regarded as a real University at all. It is that the University School should itself be a centre of inspiration for the engineering profession; that it should be a place where original experimental work is always being carried on, where inventions are tried out, and where engineering firms may come for help in carrying out tests and experiments to advance technical knowledge, and particularly to assist in the solution of engineering problems of special importance to the State.

All the large modern engineering and manufacturing corporations have realized the value of scientific research. In these times they could not hold a foremost position without it. In the U.S.A. more than fifty industrial concerns have established research laboratories on an extensive scale. The Eastman Kodak, General Electric, American Rolling Mill Co., Detroit Edison Co., and others

spend as much as £20,000 to £60,000 a year on research work. In this State, our engineering and manufacturing enterprises are, as a rule, too small to be able to provide research departments of their own, and for that very reason a well-equipped University laboratory is of the more importance, for it could give assistance in many difficulties.

During the war I visited a large workshop near Melbourne, where an attempt had been made to start in Australia the manufacture of copper tubes, then unobtainable from abroad. A plant was erected at a cost of several thousands of pounds, the very purest electrolytic copper, containing as much as 99.9 per cent. of pure copper, was purchased, expert workmen were engaged, but the tubes could not be drawn. For some reason the copper was not sufficiently ductile. For nine months experiments were tried, and a great deal of money was spent without success. As a last resort, a young Melbourne graduate was employed, who had given special attention to the examination of metals by the metallurgical microscope. He found that the slight impurity present consisted of oxygen united with the copper as an oxide. Cuprous oxide contains about 11 per cent. of oxygen, and in this case it was present chiefly in the form of minute layers in between layers of pure copper, forming a structure known as the eutectic. The result was that although the oxygen formed less than 0.1 per cent. of the whole, the eutectic, in which the oxide was intimately woven, formed as much as 20 per cent. of the whole. Now cuprous oxide is not ductile, and the eutectic in consequence was a brittle structure. Moreover, it arranged itself round the boundaries of the pure copper crystals so as to destroy their cohesion. Here then was the cause of the trouble, and the problem was to destroy the structure of the eutectic. Experiment showed that this could be done by a special treatment that induced the oxide particles to form into globules, so that when the metal solidified it did so prac-

tically as a pure metal with a few globules of oxide scattered throughout it. When this was done the tubes were drawn easily and well. Science succeeded where experience had failed.

This is an example of the kind of difficulty in which a well-equipped University laboratory might be of the greatest assistance to the manufacturing community. As it is, with our present limited resources, we do something, but much more would be possible if our equipment were sufficient. To do this sort of thing efficiently requires, of course, laboratories, apparatus, and suitable assistance, and all this costs money. Clearly the exuberant enthusiasm of the professor must be kept within bounds. We cannot expect the State of South Australia, with a population of less than half a million of people, and with the demands upon its revenue due to the vast area that it covers, can afford to provide the same facilities for research work that are given at Manchester or Columbia. But that is no reason why we should do nothing. No one in touch with engineering practice will deny that there are plenty of problems that S.A. engineers would like to have solved, many of them, like that of our brown coals, being local problems that we can scarcely expect outsiders to solve for us.

Let me illustrate the value to the nation of scientific research, combined with engineering invention, by a story from our own recent history. In 1905 Mr. A. G. M. Michell, a graduate in Engineering of Melbourne University, published the results of an elaborate mathematical investigation into the flow of lubricating oils under certain conditions. As the result of his mathematical work, which was of a very high-class character, he made certain remarkable deductions, which he verified by ingenious experiment. He deduced that it should be possible to construct a thrust bearing, such as that required on the main propeller shaft of a ship, in which metallic contact of moving surfaces would be

entirely eliminated and the only frictional resistance would be that due to the viscosity of the oil used. He proceeded to apply his idea to the practical construction of thrust bearings, but, so revolutionary were his proposals, that it was not till the beginning of the war in 1914 that marine engineers could be persuaded to use them. Then they made rapid headway. The Admiralty adopted them, and now all new British warships, as well as most other new vessels, are fitted with Michell thrust bearings. In 1919 an application was made before the Chancery Court in England for renewal of the patent rights, and was supported by the Admiralty. In granting the application, the judge stated that it was no exaggeration to describe the invention as an epoch-making one. The use of the gear-driven turbine, as it was practised in the Navy throughout the war, including its use in submarines, and as it is now being used in fast commercial vessels, was rendered possible only by the use of this type of bearing. It was given in evidence that its application to a battle cruiser resulted in a saving in initial cost of £38,000, and a further saving of 3 per cent. in the amount of coal used, as well as a reduction in the quantity of oil. The annual saving to the Navy alone in coal and oil was given as at least £800,000. It was a notable Australian contribution to the Allied cause in the great war.

It is no exaggeration to say that the invention has not only enabled us to do something that we could not do before, but to the British nation it has resulted in the saving altogether of millions of pounds worth of coal and oil. The direct monetary gain to the nation from this one invention has certainly been a great deal more than the whole of the money spent upon Melbourne University from its inception. Of course, the invention might still have been made had the Melbourne University not been in existence. But it is safe to say that the invention would not have been possible unless somehow or other Mr. Michell had had the

opportunity to obtain a thorough training in mathematical science.

That the provision of proper facilities for research may be an exceedingly profitable investment from a commercial point of view has been amply demonstrated by events. That it will be profitable to a young nation in a better sense I firmly believe. We have taken pride in the remarkable powers of self-reliance and initiative that were shown by our Australian soldiers in the great war. We perhaps flatter ourselves that these are qualities that are bred in the clear skies and broad expanses of our Australian continent. As a nation in the making, we have reason to be proud and hopeful of the future when we see these qualities united with dauntless courage in tens of thousands of our youth. But we cannot develop the best spirit of self-reliance in the nation if we are for ever to depend upon other peoples to show us the way to progress and be content to simply follow them. We have our own problems that require their own solutions, and it should be our ambition to lead the way and not follow in the wake. The war is over, but the competition between nations continues. It cannot be diminished by Peace Conferences nor evaded by philanthropic projects. It is the law of Nature, and if we would survive we must prove ourselves to be fit. We cannot do that if we neglect the development of the highest qualities of the human mind, the qualities upon which human progress has chiefly depended.

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